Sustainable Rehabilitation of the Hawkshaw Bridge Piers through Structural Overbuild and Galvanic Anode Technology

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ABSTRACT

The Hawkshaw Bridge (H385), spanning the Saint John River at Pokiok, New Brunswick, is a mid-twentieth century reinforced concrete structure that by 2024 exhibited significant chloride-induced deterioration across its substructure, including the north and south abutments, anchor pier, and tower piers 1 and 2.[2,4] Conventional concrete patching alone could not adequately address the underlying corrosion mechanism; without active corrosion mitigation, macrocell current flow at repair boundaries would initiate new deterioration in adjacent chloride-laden concrete.

This paper describes the integrated structural overbuild and embedded galvanic anode cathodic protection strategy developed for the Hawkshaw Bridge under NB DTI Contract 25-0816.[2] The corrosion protection system employed two complementary galvanic anode types: distributed anodes for broad-area protection embedded within the concrete overbuild, and point anodes placed at patch repair perimeters to eliminate halo effect activity. Together, these systems protect both existing and newly embedded reinforcing steel across all treated substructure elements.[3]

The paper details the corrosion problem, the electrochemical principles underpinning the solution, the element-specific anode design methodology, the concrete compatibility requirements, the installation procedure, and the expected long-term performance outcomes. The Hawkshaw Bridge project demonstrates that structural overbuild combined with embedded galvanic cathodic protection is a durable, low-maintenance, and environmentally responsible strategy for achieving a 30-year service life extension for aging reinforced concrete bridge substructures.

1. INTRODUCTION

Chloride-induced corrosion of reinforcing steel is the leading cause of premature deterioration in reinforced concrete bridge substructures across Canada. The combination of road de-icing salts, freeze-thaw cycling, and long-term service exposure creates conditions that allow chloride ions to penetrate the concrete cover, reach the reinforcing steel, and initiate the electrochemical corrosion process. Once corrosion is underway, the expansive iron oxide products generated at the steel surface generate tensile stresses that crack and spall the surrounding concrete, accelerating further chloride ingress and structural deterioration. Left unaddressed, this process progressively degrades structural capacity, increases maintenance costs, and ultimately threatens the safety and serviceability of the structure.

The typical first response, concrete patch repair, addresses visible deterioration but does not arrest the underlying corrosion process. Worse, patch repairs can actually accelerate deterioration in the surrounding concrete through a mechanism known as the “halo effect.” When a cathodic patch repair is placed in contact with anodic, chloride-contaminated concrete, a macrocell is established: current flows from the surrounding contaminated concrete, which acts as the anode, to the repair zone, driving accelerated corrosion initiation at and around the patch perimeter. This phenomenon means that without corrosion mitigation, patch repairs can generate new deterioration in the concrete immediately adjacent to the repair, often within a few years of application.

Effective, durable rehabilitation of chloride-damaged concrete bridge substructures therefore requires not just physical repair of visible deterioration, but an active strategy to suppress ongoing corrosion in both repaired and adjacent zones. Galvanic anode cathodic protection using zinc-based anodes embedded directly in the concrete provides exactly this capability.[9] By imposing a small protective cathodic current on the reinforcing steel, galvanic anodes shift the electrochemical potential of the steel away from the corrosion range, arresting active corrosion and preventing its initiation in adjacent zones. The system

operates autonomously, powered entirely by the electrochemical potential difference between zinc and steel, requiring no external power supply, no monitoring infrastructure, and no ongoing maintenance interventions.

The Hawkshaw Bridge rehabilitation project provides a compelling case study in the application of embedded galvanic anode cathodic protection as an integral component of a structural concrete overbuild program for a major river-crossing bridge. This paper focuses on the corrosion protection strategy: the problem it addresses, the science behind it, the design methodology applied, and the installation approach adopted across the bridge's five major substructure elements.

2. PROJECT BACKGROUND AND CONDITION ASSESSMENT

2.1 Structure Description

The Hawkshaw Bridge (NB DTI structure H385) is located at Pokiok in York County, New Brunswick, in the Parishes of Dumfries and Southampton.[4] The structure crosses the Saint John River and forms a critical link in the regional transportation network, carrying passenger and commercial traffic between communities on both banks. Built in the mid-twentieth century, the bridge has provided continuous service for decades. Its substructure comprises five major elements: a north abutment, a south abutment, an anchor pier, and two tower piers (Tower Pier 1 and Tower Pier 2). The approach span connects the north abutment to the anchor pier; the main span connects the south abutment through the anchor pier.

The bridge operates in an environment that is highly conducive to chloride-induced concrete deterioration. Road de-icing salts applied to the bridge deck migrate through the deck surface and down the substructure, while spray and seasonal flooding expose the lower pier and abutment elements to river water. Freeze-thaw cycling exacerbates the physical deterioration of chloride-damaged concrete. These combined environmental stressors, acting over several decades of service, created the conditions that necessitated the 2025–2026 rehabilitation program.

2.2 Condition Assessment Findings

Condition assessment of the Hawkshaw Bridge substructure, completed prior to the development of the rehabilitation design, identified low to moderate chloride concentrations throughout the concrete of the piers and abutments.[2,4] This finding is consistent with decades of exposure to road de-icing salts and the river environment, and places the reinforcing steel at risk of active corrosion across all five substructure elements. The deterioration observed in the field included concrete cracking, surface spalling, and delamination at the abutment faces, wing walls, and shelf areas, as well as at the exposed faces of the anchor pier and tower pier columns. In several locations, the deterioration had progressed to the point of reinforcing steel exposure.

Critically, the chloride concentrations measured in undamaged-appearing concrete adjacent to existing deterioration zones confirmed that the corrosion process was not confined to visibly damaged areas. Chloride-contaminated concrete surrounding existing and future repair zones presented a clear halo effect risk: without corrosion mitigation integrated into the repair program, macrocell activity at repair perimeters would be expected to drive new deterioration within a few years of repair completion. The condition assessment therefore concluded that a standalone concrete repair program was insufficient, and that an active corrosion mitigation strategy designed to protect both the repaired areas and the surrounding chloride-contaminated concrete was essential to achieving the target 30-year service life extension.

2.3 The Halo Effect: Why Patching Alone Is Not Enough

The halo effect is a well-documented phenomenon in the repair of chloride-contaminated reinforced concrete.[5,9] When a concrete repair is placed over corroding reinforcing steel, the repaired zone becomes cathodic relative to the surrounding chloride-contaminated concrete: the repair concrete is typically free of chlorides, has a higher pH, and re-passivates the steel within its boundaries. However, the reinforcing steel in the surrounding concrete remains in an active corrosion state. The electrical continuity of the reinforcing steel network means that current flows from the anodic surrounding zones into the cathodic repair zone, intensifying anodic dissolution and therefore corrosion of the reinforcing steel at and beyond the repair perimeter.

Field observations from bridges repaired without corrosion mitigation consistently show that new cracking and spalling emerge in the concrete adjacent to patch repairs within two to five years of application, forming a characteristic “halo” of new deterioration around each repair.[9] This pattern results in escalating maintenance requirements, increasing costs, and ultimately a shorter effective service life than if a more comprehensive rehabilitation had been undertaken at the outset. The point anode system is specifically designed to address this mechanism: by installing galvanic anodes around the perimeter of each repair area, the electrochemical gradient that drives macrocell activity is reversed, protecting the adjacent concrete and preventing halo effect deterioration from developing.

3. STRUCTURAL OVERBUILD AS THE REHABILITATION FRAMEWORK

3.1 Concept and Rationale

The rehabilitation strategy for the Hawkshaw Bridge substructure is built around the concept of a structural concrete overbuild: the addition of a new concrete layer over the existing, deteriorated structural elements, bonded to the prepared existing substrate and reinforced with new steel that is made electrically continuous with the existing reinforcing. This approach differs from conventional patch repair in both its extent and its intent. Rather than targeting only visibly deteriorated areas, the overbuild encapsulates the entire exposed face of each treated element, providing a uniform new concrete cover over the existing structure.

The overbuild serves multiple functions simultaneously. Structurally, it restores and in some cases enhances the cross-sectional capacity of deteriorated elements. Physically, it eliminates the chloride-contaminated concrete surface layer and replaces it with a fresh, low-permeability concrete that limits future chloride ingress. And critically for the long-term performance of the rehabilitation, the overbuild provides the matrix within which the embedded galvanic anode cathodic protection system is installed. The new concrete encapsulates the distributed anodes, ensuring full electrolytic contact between the anodes and the reinforcing steel they are designed to protect. The anodes and the concrete overbuild together form a single, integrated system: neither is fully effective without the other.

Concrete removal prior to overbuild placement followed Type A partial-depth removal procedures in accordance with ICRI standards.[6] Saw-cut perimeters were used to provide clean, vertical edges at repair boundaries, and the concrete substrate was abrasive-blasted to achieve the surface profile required for adequate bond between the existing concrete and the new overbuild material. Repair concrete mixes were selected to meet stringent performance requirements including low shrinkage, high tensile bond strength, and critically, a bulk electrical resistivity below 50,000 ohm-cm to ensure compatibility with the embedded galvanic system.[8]

3.2 Electrical Continuity — The Critical Prerequisite

The effectiveness of any galvanic cathodic protection system depends on the electrical continuity of the reinforcing steel network to which the anodes are connected.[5,9] Before any anode installation could proceed, the contractor was required to verify the electrical continuity of all existing reinforcing steel using a calibrated multimeter. A DC resistance measurement of 1 ohm or less, or a DC voltage measurement of 1 mV or less between any two points on the reinforcing network, was required to confirm adequate continuity.[3] Where discontinuities were identified due to corrosion-induced breaks in the rebar or inadequate lapping in the original construction, the bars were bonded to the continuous reinforcing network using uncoated steel tie wire.

All new reinforcing steel introduced as part of the overbuild was required to be made electrically continuous with the existing reinforcing prior to concrete placement. Dowel bars drilled and grouted into the existing concrete using epoxy mortar were used to mechanically and electrically connect the new overbuild reinforcement to the parent structure. This continuity requirement was not merely a quality assurance formality: it is the physical mechanism through which the galvanic anode system delivers protective current to the reinforcing steel. A discontinuous rebar network would leave isolated steel segments unprotected, defeating the purpose of the cathodic protection system.

4. CATHODIC PROTECTION SYSTEM DESIGN

4.1 System Overview and Design Philosophy

The cathodic protection system comprises two complementary galvanic anode products deployed in a coordinated dual-function strategy:

- Distributed anodes: linear anodes embedded within the concrete overbuild across the full treated area of each substructure element, providing broad-area galvanic protection to both existing and newly embedded reinforcing steel over a 30-year design life.[3]
- Point anodes installed along the perimeter of individual patch repair areas, specifically targeting the halo effect mechanism by delivering protective current to the reinforcing steel at and immediately beyond each repair boundary, over a 20-year design life.[3]

This dual-technology approach reflects the two distinct corrosion risk scenarios present at the Hawkshaw Bridge: broad-area chloride exposure across the full faces of the abutments and piers, addressed by the distributed system; and localized macrocell activity at repair perimeters, addressed by the point anodes. The design philosophy is to provide the minimum current density necessary to achieve electrochemical protection of the reinforcing steel at each location, tailored to the specific exposure conditions and geometry of each structural element, over the required design life.

Both anode products are zinc-based, alkali-activated with cementitious matrices at pH 14 or greater, and contain no intentionally added chloride, bromide, or other halides that could be harmful to reinforcing steel.[5,7] This is an important specification requirement: the use of chloride-containing activators in galvanic anode systems, sometimes employed to increase initial current output, is incompatible with the goal of long-term corrosion protection and was explicitly prohibited.

4.2 Distributed Anodes — Design Parameters

4.2.1 Design Basis

The distributed anode system design for the Hawkshaw Bridge was based on the following parameters, consistent with the performance data validated from long-term field monitoring of comparable installations:[3]

- Minimum service life: 30 years
- Minimum current density delivered over the service life: 0.6 mA/m²
- Efficiency and utilization factor: 75%
- Anode aging factor: 12.5 years (the period over which the current output of the installed anode decreases to half of its initial value, at an average annual structure temperature of 10–15°C)
- Chloride risk following concrete removal: low to moderate

The aging factor is a key parameter in long-term anode performance modelling. It represents the rate at which the electrochemical activity of the installed anode decreases over time as the zinc is consumed and the activation state of the cementitious matrix evolves. The 12.5-year aging factor is derived from monitored field performance data from actual installations, not laboratory estimates, ensuring that the design current density is achievable under real-world conditions over the full 30-year design life.[3,9]

4.2.2 Element-Specific Anode Layout and Spacing

The horizontal spacing of distributed anode rows for each structural element was determined based on the chloride risk assessment, the geometry of the element, and the current density required to achieve the 30-year design life at the specified minimum protection level.[3] Tighter spacing delivers a higher current density to the reinforcing steel; wider spacing is appropriate where the chloride risk is lower and the required current density is correspondingly less. The following element-specific spacings were specified in the shop drawings:[3]

- North Abutment — upper face, lower face, shelf, and wing walls: 710 mm
- South Abutment — upper face and wing walls: 500 mm
- South Abutment — lower face and shelf: 710 mm
- Anchor Pier — flat faces (north and south): 530 mm
- Anchor Pier — sloped face and faces at cold joints: 430 mm
- Anchor Pier — top surface: 500 mm
- Tower Pier 1 and Tower Pier 2 — pier caps: 350 mm

The tighter 350 mm spacing at the tower piers reflects both the higher chloride exposure risk at these elements, which are subject to direct road salt exposure from above and river water exposure at their lower sections, and the higher reinforcement density in these elements: for their size, the tower piers contain heavy reinforcement relative to the mass concrete volumes, increasing the protected steel surface area per unit volume of concrete compared to elements such as the anchor pier. The 430 mm spacing at the anchor pier sloped face and cold joint locations reflects the greater geometric complexity of these areas and the elevated risk of chloride penetration at construction joints. An additional row of distributed anodes was specified immediately below the start of the sloped face on the anchor pier to ensure full coverage at this geometrically challenging transition.

Anodes were placed parallel to and in direct contact with the upper layer of reinforcing steel, secured using the integral tie wires. Where bi-directional reinforcing steel was present, the anodes were run parallel to the upper layer. The anodes were secured to prevent movement during concrete placement, and concrete was consolidated around each anode to ensure full encasement with a minimum of 38 mm cover to the exterior concrete surface, in accordance with the manufacturer's installation requirements.[3]

4.3 Point Anodes — Design Parameters

4.3.1 Design Basis

The point anode system was designed to deliver a minimum current density of 0.8 mA/m² to the reinforcing steel adjacent to each repair area over a 20-year design life.[3] This current density is sufficient to suppress macrocell activity at the repair perimeter and prevent halo effect deterioration from developing. The design took into account an anode aging factor derived from field monitoring of point anode installations in service environments comparable to the Hawkshaw Bridge, and the expected in-service temperature and humidity conditions in New Brunswick.

4.3.2 Element-Specific Spacing

Point anodes were installed at the perimeter of all patch repair areas across the treated substructure elements, with element-specific spacings as follows:[3]

- South Abutment — upper face and wing walls: 250 mm
- South Abutment — lower face and shelf: 350 mm
- North Abutment — upper face and wing walls: 300 mm
- North Abutment — lower face, shelf, and beneath bearing pad zones: 450 mm
- Tower Pier 1 and Tower Pier 2 — diaphragm walls: 310 mm in a grid pattern

Tighter spacings at the south abutment upper face and wing walls (250 mm) reflect the higher chloride exposure at these elements and the correspondingly greater halo effect risk. At the tower pier diaphragm walls, point anodes were installed in a grid pattern at 310 mm spacing, providing comprehensive coverage across the full face of each diaphragm in addition to the perimeter protection at individual repair boundaries.

4.4 Installation Methodology

4.4.1 Surface Preparation and Steel Cleaning

All concrete removal was carried out in accordance with ICRI repair standards.[6] Saw-cut perimeters established clean, vertical edges at repair boundaries. Abrasive blasting was used to clean both the concrete substrate and the exposed reinforcing steel. Reinforcing steel was cleaned of rust, mortar, and other contaminants to provide adequate electrical contact for anode connection and mechanical bond for the new concrete. Where significant cross-sectional loss of reinforcing steel was identified, supplemental reinforcement was installed and made electrically continuous with the existing rebar network. The cleaned substrate was brought to a saturated surface-dry condition prior to concrete placement, as required for adequate bond of the overbuild concrete.[8]

4.4.2 Point Anode Installation at Repair Perimeters

Point anodes were installed following a standardized four-step procedure. First, the anode was placed parallel to and snug against the cleaned reinforcing steel bar, as close as possible to the repair perimeter

interface, within 100 mm of the boundary between the repair concrete and the parent concrete. One tie wire was fed over the rebar and one under; both wires were then pulled tightly around the bar, wrapping one full revolution outward from the anode and bringing the free ends to the back of the rebar. The two wire ends were twisted together using a wire hook tool until all wire was tight against the rebar, and the twisted ends were bent flat against the bar. Electrical continuity of each anode-to-rebar connection was confirmed using a multimeter before repair concrete was placed.

Where repair concrete mixes with a saturated bulk resistivity exceeding 50,000 ohm-cm were used, a low-resistivity mortar pocket was placed around each point anode, extending a minimum radius of 50 mm from the anode. This mortar pocket creates a conductive bridge between the anode and the surrounding higher-resistivity repair concrete, ensuring adequate ionic conductivity for current delivery.

4.4.3 Distributed Anode Installation Within the Overbuild

Distributed anode installation within the concrete overbuild followed the layout defined in the shop drawings.[3] Anodes were laid out at the specified element-specific horizontal spacings, running parallel to the upper layer of reinforcing steel. The integral stainless steel tie wires were wrapped around the reinforcing bars multiple times in opposite directions, with the free ends twisted tight using pliers, and additionally secured with plastic cable ties where required to prevent movement during concrete placement. The anode tie wires were connected to the reinforcing steel grid at a minimum of two connections per 46 m² of concrete area, ensuring adequate electrical connectivity of the anode network to the reinforcing steel it protects.

Following anode installation, the electrical continuity of each anode connection to the reinforcing steel was verified using a multimeter. A DC voltage reading of less than 1 mV was required to confirm good continuity before proceeding to concrete placement. Only after all continuity requirements were confirmed was the overbuild concrete placed, consolidating fully around the anodes to eliminate voids and ensuring the minimum 38 mm concrete cover was achieved over every anode unit.

4.5 Concrete Compatibility with the Galvanic System

The effectiveness of an embedded galvanic anode cathodic protection system depends not only on the electrochemical properties of the anode itself but also on the electrical resistivity of the surrounding concrete.[5,9] Ionic conductivity between the zinc anode and the reinforcing steel, the medium through which the protective current is delivered, is inversely proportional to the concrete's bulk electrical resistivity. Concrete mixes with high resistivity, typically those containing elevated levels of supplementary cementitious materials such as silica fume, ground-granulated blast-furnace slag, or fly ash, may impede current flow and reduce the effective protection delivered by the anodes.

The contract specifications required that all concrete mixes used with the galvanic protection system have a bulk electrical resistivity of less than 50,000 ohm-cm at 28 days, measured in accordance with CSA-A23.2-26C.[2,8] Concrete mixes proposed by the contractor were required to be pre-qualified through testing against this threshold, along with tensile strength (minimum 2.0 MPa at 28 days), drying shrinkage (maximum 0.04% after 28 days), and restrained shrinkage cracking resistance (no cracking within 14 days per AASHTO T363), and approved by the engineer before any concrete was placed. These specification requirements reflect the intent to ensure full electrochemical compatibility between the repair concrete and the embedded galvanic system; where the resistivity threshold cannot be met by the specified mix, the use of a low-resistivity mortar pocket around each anode location provides a reliable means of maintaining adequate ionic conductivity for current delivery.

Tensile bond strength of the hardened overbuild concrete to the existing substrate was also specified to be verified through testing, at a minimum frequency of two tests per encapsulated structure, with a minimum acceptable bond strength of 0.9 MPa at 28 days per CSA A23.2-6B.[8] This testing protocol is intended to confirm the adequacy of substrate preparation and concrete placement procedures for achieving durable long-term bond between the overbuild and the parent structure.

5. EXPECTED PERFORMANCE AND LIFECYCLE BENEFITS

5.1 Corrosion Protection Performance

The galvanic anode cathodic protection system installed at the Hawkshaw Bridge is designed to deliver sustained protective current to the reinforcing steel across all treated substructure elements for the duration of its design life: 30 years for the distributed system and 20 years for the point anodes.[3] The performance model, developed and verified against field monitoring data from comparable installations, confirms that the specified current densities are sufficient to shift the electrochemical potential of the reinforcing steel into the protection range, arresting active corrosion and preventing its initiation in adjacent chloride-contaminated zones.[9]

The use of an anode aging factor derived from long-term field monitoring data is a critical element of the performance confidence.[3,9] Unlike laboratory-derived aging estimates, field-validated aging factors account for the real-world variability of in-service conditions, including temperature fluctuations, humidity variations, and the complex electrochemistry of concrete with variable chloride contamination and varying degrees of rebar passivation. The aging factor used for the distributed anodes at the Hawkshaw Bridge corresponds to the period over which the current output of the installed anode is expected to decrease to half of its initial value under Atlantic Canadian temperature conditions, and has been confirmed through field monitoring of installations with at least seven years of performance data.

The point anodes, installed at all patch repair perimeters across the treated elements, provide targeted protection against the halo effect mechanism. By maintaining a cathodic protection current in the reinforcing steel at and around each repair boundary, the system prevents the macrocell activity that would otherwise drive new corrosion initiation adjacent to the repairs. Field evidence from bridges where point anodes have been installed in comparable repair programs consistently demonstrates the absence of halo effect deterioration at protected repair perimeters over observation periods of ten years or more.[9]

5.2 Lifecycle Value and Sustainability

The decision to pursue structural overbuild with integrated galvanic cathodic protection, rather than conventional patch repair or full bridge replacement, reflects a lifecycle value optimization that delivers benefits across multiple dimensions. Compared to a conventional patch repair program without corrosion mitigation, the integrated approach is expected to significantly reduce the frequency of future maintenance interventions required to address ongoing chloride-induced deterioration, lowering long-term asset management costs for the owner. The 30-year service life extension targeted by the program represents a substantial deferral of the capital expenditure that would otherwise be required for more extensive structural intervention or replacement.

Compared to full bridge replacement, the rehabilitation approach avoids the substantial embodied carbon associated with demolition and new construction: the energy and emissions required for material extraction, processing, transportation, and in-situ placement of the large volumes of concrete and steel that a new structure would entail. The galvanic anode systems themselves contribute minimal

environmental impact over their service lives, operating as passive, self-powered devices with no external power consumption, no chemical additives, and no waste streams requiring disposal. The zinc anodes are gradually consumed over their design life, but the consumption rates are small and the products of zinc oxidation are benign in the concrete environment.

The self-powered, passive operating mode of the galvanic anode systems is particularly well-suited to the operational context of a remote river-crossing bridge where access for routine maintenance is limited.[9] Unlike impressed current cathodic protection systems, which require a continuous external power supply, periodic inspection of electrical components, and regular adjustment of output current, the galvanic systems require no ongoing intervention once installed. This characteristic significantly reduces the long-term operational cost of the corrosion protection system and eliminates the risk of corrosion protection failure due to power interruptions or system component failures.

6. CONCLUSIONS

The Hawkshaw Bridge rehabilitation project demonstrates the effectiveness of embedded galvanic anode cathodic protection as an integral component of a structural concrete overbuild program for aging reinforced concrete bridge substructures. The following conclusions are drawn from the project design and implementation:

- Conventional concrete patch repair without corrosion mitigation is insufficient for achieving long-term service life extension in chloride-damaged reinforced concrete bridge substructures. The halo effect mechanism must be actively addressed to prevent early re-deterioration of repaired areas.[5,9]
- The combination of distributed anodes within the concrete overbuild and point anodes at repair perimeters provides a comprehensive dual-function corrosion protection strategy: broad-area protection of both existing and new reinforcing steel across the full treated element face, and targeted halo effect suppression at individual repair boundaries.[3]
- Element-specific anode spacing, determined through current density modelling based on chloride risk assessment and validated anode aging factors, is essential for optimizing system performance and long-term value.[3] Spacings at the Hawkshaw Bridge ranged from 250 mm at high-risk locations to 710 mm at lower-risk elements, with reinforcement density an additional contributing factor at elements such as the tower piers.
- Electrical continuity of the reinforcing steel network is the critical prerequisite for galvanic cathodic protection system performance.[5,9] Continuity verification before and after anode installation, using quantitative multimeter testing with defined acceptance criteria, is a non-negotiable quality assurance requirement.
- Concrete mix electrical resistivity must be considered alongside traditional mechanical properties.[8] Where mixes with bulk resistivity exceeding 50,000 ohm-cm are used, supplemental low-resistivity mortar pockets at anode locations provide a reliable means of maintaining adequate ionic conductivity for current delivery.
- CSA S806[1] establishes that all active deterioration mechanisms must be stabilized before FRP application. This principle has important implications for the design and sequencing of integrated rehabilitation programs combining cathodic protection with FRP confinement on chloride-damaged bridge piers.

- The integrated structural overbuild and galvanic cathodic protection approach offers compelling lifecycle value: it extends structure service life by 30 years, reduces future maintenance burden, avoids the embodied carbon of new construction, and requires no external power or ongoing operational intervention.

The Hawkshaw Bridge project provides a replicable model for the rehabilitation of aging reinforced concrete bridge substructures across Canada, particularly in cold-climate, road-salt-intensive environments where chloride-induced corrosion is the dominant deterioration mechanism. The design methodology, installation procedures, and quality assurance protocols documented in this paper are directly applicable to comparable rehabilitation programs across the Atlantic provinces and beyond.

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